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OUTLOOK AND PERSPECTIVES (EXCITED BARYONS - 1988)

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CEBAF

The audience is still here, that is a good sign. The title of my talk is "Outlook and Perspectives" and, like everybody else, I am going to change the title of my talk. It is going to be "Perspectives and Outlook". So I want to spend the first part of it on perspectives.

This is a workshop on excited baryons with B=1. The baryon is the fundamental building block of nature. Without baryons we would not be here. And we really should put things in perspective. I was impressed by the transparency that Golowich showed (Figure 1). It illustrates the real explosion of knowlege within a single lifetime. Eric Vogt in his summary talk at the CEBAF Workshop said: "God created the 'great knowledge machine' in this era", and it is really true. The proton in 1905; the nucleus in the first decade of the twentieth century; the neutron in 1932, the same year I was born, so that everything else happened within my own lifetime; the discovery of the pion and the delta; the concept of quarks; scaling, deep–inelastic lepton scattering, and partons; and the theory of QCD. All these occurred within the time span of a single lifetime.

We are talking about the baryon. I took the tables handed out here and plotted the spectrum (Figure 2). I tried to put the quantum numbers on and there was not even enough room for the quantum numbers. It is a complicated system. The left side shows the strangeness-zero sector, and T=1/2 and T=3/2 states; the right is the strangeness-minus-one sector. We can, of course, access the left sector with electron scattering (e, e'). We can also access the right sector with the $(e, e'K^+)$ reaction, if we have enough energy. The main impression of the spectrum is that the baryon is a complicated system with lots of resonances.

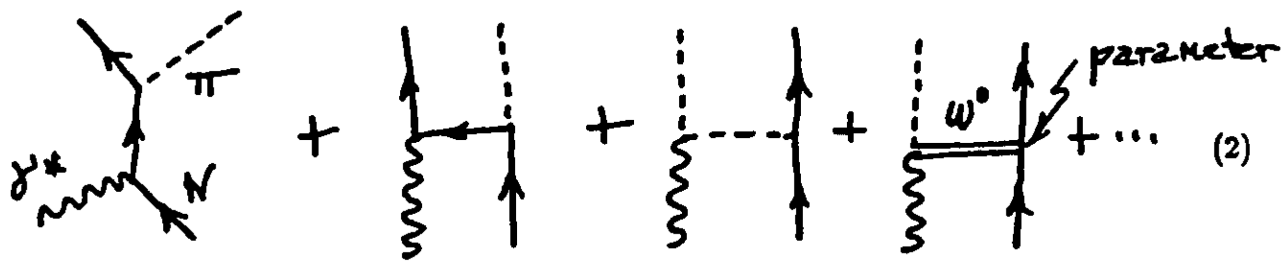
I am going to emphasize the electromagnetic interaction in this talk for fairly obvious reasons, but we have heard this afternoon about plans for new hadron facilities. You really need hadron facilities as well as electromagnetic facilities. They are really complementary and, in fact, I do not think you can get very far in this game by emphasizing one at the expense of the other.

For perspective, I want to show you some electron scattering spectra in Figures 3 and 4. In fact, these are some of the original SLAC data taken when SLAC just turned on [1,2]. The data is, of course, still good. This is what we are going to see at CEBAF. This is the inclusive spectrum. Figure 3 shows the data at 7 GeV incident energy and 6 degrees. The elastic peak is suppressed so the first peak is the delta. As we have seen many times at this workshop, although the spectrum of the nucleon is complicated in terms of resonances, if you look here you see only four structures. The reason for this is that the resonances are broad, overlapping structures in the nucleon. Except for the $\Delta(1236)$, maybe the N(1520), and maybe the $\Lambda(1405)$, the excited states of the baryon are broad overlapping resonances, so it is indeed a complicated system. The first peak is the delta, the next is the 1520 resonance region, the third is the 1688 resonance region, and there is something up here at about 1950. Figure 4 shows what you see if you do the same experiment at 10 GeV incident energy. Again, there are three structures and maybe a fourth structure. There is a lot of background, in fact, and the resonance curves I will show were obtained by simply assuming a smooth polyonomial background and making Breit-Wigner resonance fits to those structures.

I want to make a comparison of the resonance structures with a very simple model [3-5]. This is a synthesis of a lot of what we heard here at this workshop. It is a model formulated in terms of hadronic degrees of freedom. It says take one of the resonant amplitudes, there are three resonant amplitudes for each one of these nucleon resonances, and write it in the following form

$$a(W,k^2) = a^{lhs}(W,k^2)/D(W) \tag{1}$$

The numerator $a^{lhs}(W,k^2)$ is a function of the total energy W in the center of momentum and of k^2, the mass of the virtual photon. The denominator is a final state enhancement factor, which I will call D(W). The numerator is meant to be the multipole projection of a covariant, gauge invariant Feynman amplitude. For example, in the calculations I will show you it is the sum of the following amplitudes.



(2)

D is a final–state enhancement factor. If you are in the elastic region, there is an expression due to Watson which involves the phase shift for $\pi - N$ scattering, in that particular channel

$$D(W) = \exp\left[-\frac{1}{\pi}\int_{W_0}^{\infty}\frac{\delta(W')\,dW'}{W'-W-i\eta}\right] \tag{3}$$

The curves I will show you are normalized to photoproduction. What is the justification for the model? Well, the amplitude is covariant; it is gauge invariant; it has the correct analytic properties; it has the correct threshold behavior; it resonates where the scattering amplitude resonates; and it satisfies unitarity. And one of the reasons I show you these curves is that the calculations were done before the experiments. I also want to convince you that in my youth I could at least do an honest calculation. For the $\Delta(1232)$ this model, in fact, summarizes a lot of work by a great many people. The original work went back to Chew, Goldberg, Low and Nambu [6]–and I give the list of some of the people who have worked on this [7–12], and there are lots of others. Why do I show this? These principles are still true. Even if you start with quarks, the amplitude that you construct must have all of these properties.

Figures 5–8 show you the ratio of inelastic to elastic cross-section for those various resonance regions for the nucleon. There is one point at $k^2 = 0$ which comes from photoproduction, and the experimental ratio of these cross-sections is shown out to 6 $(\mathrm{GeV})^2$ momentum transfer; it is compared with the value calculated from this hadronic model. Figure 5 is for the $\Delta(1236)$. Figure 6 is for the bump in the 1520 resonance region. Again, the various contributions were normalized to photoproduction. It is essentially the $(3/2^-, 1/2)$ that dominates the model calculation shown as Curve I. Curve II is a coupled-channel version of the same model. Figure 7 shows the 1688 region, again out to 6 $(\mathrm{GeV})^2$. Here the calculations indicate that the $(5/2^+, 1/2)$ dominates. Figure 8 is the 1950 region, with big error bars. The calculation is for the $(7/2^+, 3/2)$ state.

Figure 9 shows the separation of the longitudinal and transverse cross-sections for the $\Delta(1236)$, again compared with the very early data. In this model, the longitudinal cross-section has a diffraction minimum.

So the spectrum is complicated in terms of the underlying resonances, but what you see in the inclusive spectrum is a very simple structure composed of broad, overlapping resonances. Figures 10 and 11 show what happens when you imbed these resonances in the nucleus, as we saw from Sealock's talk at this workshop. Figure 10 shows what happens when you put the nucleon in carbon. One sees the quasi-elastic peak and also studies what happens to the delta at higher and higher momemtum transfers. The thing that impresses you about this data is that it is essentially structureless. The inclusive cross-section at the highest momentum transfer has little discernable structure.

So we have reviewed the hadronic description of the gross properties of what you see in inclusive electron scattering from the baryon in the resonance region.

Where are we today? Well, we have a standard model of the strong and electroweak interactions [13,14]. Dick Dalitz wrote down the lagrangian of QCD, which is the lagrangian for the strong interactions governing the formation of the hadrons out of the underlying quark and gluon degrees of freedom. I want to write it down again for you, in my notation. We first introduce a quantum field with three components, say red, green, and blue

$$\underline{\Psi} \equiv \begin{pmatrix} \psi_R \\ \psi_G \\ \psi_B \end{pmatrix} \tag{4}$$

This is a very compressed notation because, in fact, each component is composed of many different flavors of quark fields, and each one of those flavors is, in fact, a Dirac field

$$\underline{\Psi} \equiv \begin{pmatrix} \psi_R \\ \psi_G \\ \psi_B \end{pmatrix} \rightarrow \begin{pmatrix} u_R \\ d_R \\ s_R \\ c_R \\ \vdots \end{pmatrix} \rightarrow \begin{pmatrix} u_{R1} \\ u_{R2} \\ u_{R3} \\ u_{R4} \end{pmatrix} \tag{5}$$

The lagrangian of QCD is then

$$\mathcal{L}_{QCD} = -\bar{\underline{\Psi}}\gamma_\mu\left(\frac{\partial}{\partial x_\mu} - \frac{i}{2} g \underline{\lambda}^a A^a_\mu(x)\right)\underline{\Psi} - \bar{\underline{\Psi}}\underline{M}\underline{\Psi} - \frac{1}{4} F^a_{\mu\nu} F^a_{\mu\nu} \tag{6}$$

You can write the lagrangian down in two lines. First, there is the gauge covariant coupling of a Yang–Mills theory; then there could be a mass term as long as the mass matrix $\underline{M}$ is the identity with respect to color. As Dalitz pointed out, the masses, at least at this level, are generated by the spontaneous symmetry breaking of the electroweak interactions. $\mathcal{F}^a_{\mu\nu}$ is the analog of the Maxwell tensor, which gives the familiar fields generated from the vector potential

$$\mathcal{F}^a_{\mu\nu} \equiv \frac{\partial}{\partial x_\mu} A^a_\nu - \frac{\partial}{\partial x_\nu} A^a_\mu + g f^{abc} A^b_\mu A^c_\nu \tag{7}$$

The one new feature in this non–abelian gauge theory is the non–linear coupling of the vector mesons necessary to keep the local gauge invariance. But that is it, gang. That is the lagrangian of the world, and all you have to do is solve the problem. You can write the lagrangian down in two lines.

Let me write down the electroweak current of the standard model:

$$J^\gamma_\mu = \left[\frac{2}{3}\left(\bar{u}\gamma_\mu u + \bar{c}\gamma_\mu c\right) - \frac{1}{3}\left(\bar{d}\gamma_\mu d + \bar{s}\gamma_\mu s\right)\right] \tag{8}$$

$$\begin{aligned} \mathcal{J}^{(0)}_\mu = \frac{i}{2}\Big[&\bar{u}\gamma_\mu(1+\gamma_5)u + \bar{c}\gamma_\mu(1+\gamma_5)c \\ &- \bar{d}\gamma_\mu(1+\gamma_5)d - \bar{s}\gamma_\mu(1+\gamma_5)s\Big] \\ &- 2\sin^2\theta_W J^\gamma_\mu \end{aligned} \tag{9}$$

Now, in fact, you should sum over colors; there are equal contributions from the red, green, and blue quarks. Equation (8) shows the electromagnetic current. It is constructed from point Dirac couplings for the quarks multiplied by the electric charge. Equation (9) is the weak neutral current. One has the familiar V–A structure with no off–diagonal terms mixing the flavors of the quarks. And the electromagnetic current is mixed in with $-2\sin^2\theta_W$.

So we have a lagrangian, and we have a set of currents. Now let me show you a cartoon in Figure 12. I like to think in terms of cartoons, we all do. Underlying this cartoon is the lagrangian discussed above. For the strong interactions we have a non-abelian, relativistic quantum field theory with intrinsic non–linear gluon couplings. It is the non–linear gluon couplings that give rise to all of the interesting features of QCD, including confinement and asymptotic freedom. So this is a cartoon of what the baryon or nucleon looks like in the standard model. There is a quark structure confined by the non–linear gluon couplings. When you take the quarks apart, the gluons presumably form some sort of flux tube. The baryon is surrounded with meson fields, the meson itself is a quark–antiquark system, again confined by the non–linear couplings of the gluon field. And when we probe this strongly–interacting system with a lepton (be it an electron, a neutrino, or what have you) through the exchange of a photon, a Z, or a W, the interaction couples directly to the quarks. The gluons are neutral; they are transparent in the standard model. The electroweak interactions are also colorblind. The color of the quarks does not matter. And of course the quarks do not get out. When you strike the quark, it is the hadron or hadrons that emerge.

The first thing to realize is that one is dealing with a strong–coupling, non–linear, relativistic, non–abelian, quantum field theory. It is quite remarkable that one can, in fact, derive some results within the framework of the standard model, which are independent of the detailed nature of the solution to the strong–coupling nuclear problem. Let me give you an example. We first truncate the Hilbert space to what I call the *nuclear domain.*

We keep only the up and down quarks and antiquarks, and for the minute throw away the heavy quarks.

$$\psi \doteq \begin{pmatrix} u \\ d \end{pmatrix} \qquad ; \text{Nuclear domain} \tag{10}$$

Let me also assume the light quarks are massless; they do have a small intrinsic mass, but let me set it equal to zero. As far as nuclear, or hadronic, physics is concerned, this ψ is now an isodoublet under the strong isospin symmetry. I can then rewrite the currents in Equations (8) and (9). In terms of this isospinor the electromagnetic current is

$$J_\mu^{\gamma} = i\bar{\psi}\gamma_\mu \left(\underset{\text{isovector}}{\tfrac{1}{2}\tau_3} + \underset{\text{isoscalar}}{\tfrac{1}{6}} \right) \psi \tag{11}$$

This first term transforms as an isovector under strong or hadronic isospin and the second term is an isoscalar. The weak neutral current can be rewritten as

$$\mathcal{J}_\mu^{(0)} = \underset{\text{isovector}}{i\bar{\psi}\gamma_\mu(1+\gamma_5)\tfrac{1}{2}\tau_3\psi} - 2\sin^2\theta_W J_\mu^{\gamma} \tag{12}$$

The first term is now an isovector with respect to nuclear isospin. This is a baryon workshop, but maybe you will let me simplify my discussion, you can also apply it to the proton and neutron, but let me use a nucleus so that I can select an isoscalar T=0 to T=0 transition. Where is the isoscalar piece of these currents? The only thing that is an isoscalar here lies in the electromagnetic current; everything else is an isovector. So that means that the weak neutral current is directly proportional to the electromagnetic current if I select isoscalar transitions. For example, the neutrino cross-section is directly proportional to the electron-scattering cross-section, with a known constant of proportionality [15].

$$d\sigma_{\substack{\nu\nu' \\ \bar{\nu}\bar{\nu}'}} = \sin^4\theta_W \frac{G^2 q^4}{2\pi^2\alpha^2} d\sigma_{e,e'}^{\mathrm{ERL}} \quad ; T=0 \to T=0 \tag{13}$$

This is an exact relation to all orders in the strong interaction. It is a marvelous relation. It holds all q^2, from long wavelengths down to the shortest wavelengths. If you scale out that factor in front and you put these two cross-sections on top of each other, then they are identical.

As another example, consider a $0^+ \to 0^+$ transition, again T=0→T=0, and look at the parity violating asymmetry in electron scattering. This is the difference of the two helicity cross-sections over the sum

$$\mathcal{A}_{ee'} \equiv \frac{d\sigma_\uparrow - d\sigma_\downarrow}{d\sigma_\uparrow + d\sigma_\downarrow} = \frac{-Gq^2}{2\pi\alpha\sqrt{2}}\left[\frac{F^{(0)}(q^2)}{F^\gamma(q^2)}\right] \quad ; 0^+ \to 0^+$$

$$= \frac{Gq^2}{\pi\alpha\sqrt{2}} \sin^2\theta_W \quad ; \begin{array}{c} 0^+ \to 0^+ \\ T=0 \to T=0 \end{array} \tag{14}$$

The result is a known constant of proportionality and the ratio of two form factors; one describes the distribution of weak neutral charge over the hadronic target, and the other describes the distribution of electromagnetic charge over the target; it is the familiar charge form factor. Again, if this is a T=0→T=0 transition, these two form factors are exactly proportional, because the currents are exactly proportional for isoscalar transitions. The ratio of form factors cancels and, in fact, the final result is a constant factor times $\sin^2\theta_W$ [16, 17]. An experiment to measure this quantity for $^{12}C(e,e')^{12}C$ is underway at Bates. I simply want to make one comment. We talked about strangeness in the nucleon at this meeting. If you include the strange quarks, you lose the simple proportionality of the currents utilized above because there are then extra pieces in the current coming from the strange quarks which are isoscalar under nuclear or hadronic isospin. You see in Equation (9) the additional isoscalar piece in the weak neutral current. The Bates experiment on carbon can, in principle, measure the strangeness content of the hadrons.

Let me go back to the cartoon in Figure 12. Now, it was an interesting workshop because we have had many, many different models of the nucleon presented and talked about here. We started with the quark shell model. We had a non-relativistic version, and we also heard about a "relativized" version of the quark shell model. These models emphasize the quark structure in this cartoon. In fact, you can get all the observed multiplets and supermultiplets with the right quantum numbers from the valence quark structure of this hadron. The MIT bag model in its original form emphasizes this part of the hadron exclusively. It simply put three massless, non-interacting quarks inside of a confinement volume. It also emphasizes the asymptotic freedom part of QCD. At very short distances, or high momemta, the interactions go away in QCD.

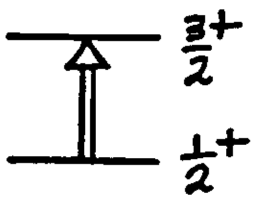
We had other models presented. We have heard about skyrmions, and we have heard about the chiral bag model. These emphasize the meson content of the hadron. There *is* a meson cloud. There is a pion tail on the nucleon, we know that, and these models simply take that part of the hadron and extend it. The former neglects, if you like, the interior core point-like quark substructure of the hadron and extends the meson field all the way inward into the origin. But you have to remember that the hadrons themselves have a quark substructure in them. The chiral bag model that Gerry Brown talked about attempts to tie the outside meson field into the interior quark structure by demanding continuity of the chiral current.

We heard this morning from Nathan Isgur about flux–tube models and strings. When I try and separate these quarks, the gluon field is confined to the region between them, and a flux–tube or string is formed. You still have to remember that you are dealing with a relativistic quantum field theory and the gluons are the quanta of the strong force binding the quarks. One has to justify treating the gluon field in a classical approximation. It is analogous to the problem of when you can treat quantum electrodynamics in terms of classical electric and magnetic fields.

Then we have also heard about calculations of hadronic properties with perturbative QCD. Again, it is a property of quantum chromodynamics that at very short distances, or very high momenta, the interactions go away. It is a free field theory and the renormalized coupling constants go to zero. One can then, in fact, do perturbation theory in the interactions with the quarks.

If I were to give my personal preferences, I think the chiral bag, or some version of it, is on the right track. There *is* an internal quark structure of the hadron. We know this from the deep inelastic scattering experiments pioneered at SLAC and since carried out other places. There *is* a point–like substructure to the hadrons. We also know there *is* a meson structure to the hadrons, you cannot deny that. We have made our living with mesons for years, and you cannot deny your heritage. It is part of the perspective. Mesons are there. They are there on the outside, and in some sense, the quarks are there on the inside. The real problem with all the models is to try and make contact with that lagrangian I wrote down in two lines in Equation (6). It is the theory of the world. And, the thing I liked about Nathan's talk is that is what he is trying to do. It is a tough job. I do not think you get the insight and understanding by simply trying to solve that theory from scratch. I think life is too complicated to do that. You *have* to use some physical insight and physical intuition. Why is life too complicated to do that? Well, look, what do you have to get out of these lattice-gauge calculations where you reduce the world to 16x16x16x16 points in spacetime. You have to generate confinement; you have to generate mesons, they are there; you have to generate the couplings of these mesons to whatever else is in there; you have to break chiral symmetry. That lagrangian that I wrote down for you in the nuclear domain with massless up and down quarks is chirally symmetric. The hadrons we observe around us are not chirally symmetric. Right? They have masses. Chiral symmetry is broken. Somehow, by solving that chirally symmetric lagrangian, you have to generate physical states where chiral symmetry is broken. It is a long, tough problem. And then these things move. There are quantum fluctuations in the meson field, so this whole hadron has an internal dynamics. It is very hard to see how you are going to get that by simply trying to solve the theory defined by that lagrangian, find the states of that langrangian, or the equivalent hamiltonian, on the small lattice. You have to use some physical insight, and that is why I think Nathan's working on the right problem.

How do you probe the hadron? Well, one way to do it is with electroproduction of resonances as illustrated in Figure 13. You scatter an electron. This gives rise to a quantum of the electromagnetic field with precisely defined frequency and precisely defined wavelength. Now if you have a CW facility, you have the chance of doing a coincidence experiment where you measure the angular distribution and energy distribution of the outgoing particles with respect to the momentum transfer (Figure 13). For example, if you have a two-body decay of the resonance, like $N+\pi$ *or* $N+\eta$ then, of course, you can use the angular distributions to try and disentangle the contributions of the various resonances which, in the inclusive cross-section, simply give rise to broad bumps. Volker Burkert talked about this in detail. The reaction $N+\eta$ is really a very promising way of looking at these resonances because it is selective. Since there are lots of broad overlapping resonances, one really would like a selective tool. One of the things I learned is that the η decay channel is a nice, selective mechanism. There has been a lot of work done on these types of analyses. A lot of work has gone on and will go on in photoproduction, as we heard from the Bonn talk. I want to just give you an example, partly to show you that in my old age I can still do an honest calculation. If you go from $1/2^+$ to a $3/2^+$



$$j \qquad N \to N^* \hookrightarrow \begin{matrix} N+\pi \\ N+\eta \end{matrix} \tag{15}$$

and look at the distribution of the pseudoscalar meson, there are four response functions that govern the general coincidence cross-section and those response functions have a characteristic angular distribution in both the azimuthal and the polar angles in the C-M

$$|\mathcal{J}_c|^2 = \frac{1}{k^*_\gamma}\,|C(\tfrac{1}{2})|^2\,\left[1+P_2(\cos\theta_\gamma)\right] \tag{16}$$

$$\begin{aligned}|\mathcal{J}^{+1}|^2+|\mathcal{J}^{-1}|^2 = \frac{1}{k^*_\gamma}\Big\{&\left(|t(\tfrac{1}{2})|^2+|t(-\tfrac{1}{2})|^2\right)\\ &+\left(|t(\tfrac{1}{2})|^2-|t(-\tfrac{1}{2})|^2\right)P_2(\cos\theta_\gamma)\Big\}\end{aligned} \tag{17}$$

$$\mathrm{Im}\,\mathcal{J}_c^*(\mathcal{J}^{+1}+\mathcal{J}^{-1}) = \frac{1}{k^*_\gamma}\left[-\frac{1}{\sqrt{3}}\,\mathrm{Re}\,C(\tfrac{1}{2})^*\,t(-\tfrac{1}{2})\right]\sin\phi_\gamma\,P_2^{(1)}(\cos\theta_\gamma) \tag{18}$$

$$Re(\mathcal{J}^{+1})^{*}(\mathcal{J}^{-1}) = \frac{1}{k^{*}_{\gamma}}\left[\frac{1}{2\sqrt{3}} Re\, t(\tfrac{1}{2})^{*} t(-\tfrac{1}{2})\right] \cos 2\phi_{\gamma}\, P_2^{(2)}(\cos\theta_{\gamma}) \tag{19}$$

The notation here is $(L,J,\lambda_n) = (1,3/2,\lambda_n) = (\lambda_n)$. You can use those characteristic angular distributions to study the resonances and to try and disentangle the contributions from the various multipoles.

That is perspective, now let me talk a little bit about outlook.

What are the problems? Let me start with theory. There are problems at various levels. I would say one is models. It is good to make models, that is how we make progress. But I would urge people to make good models, in the sense that you do consistent calculations with the minimal set of assumptions. You want a model that works pretty well but breaks down spectacularly in some place. You want to believe it really breaks down, and you want to learn something from that. So you want to make a minimal set of assumptions, then you want to calculate with that model, and then you want to compare with experiment. That is how you make progress by making models.

You also want to connect models. We are in an interesting situation, and this has been touched on several times at this workshop. Basically, we do hadronic or nuclear physics in these "low energy" discussions. We use our physical insight and try to make models of the hadronic structure of the nucleon. On the other hand, the dynamic evidence we have for quarks comes from deep inelastic scattering where we have scaling, structure functions, EMC experiments and, for example, we learn about the spin structure of the proton. In the deep inelastic domain we make a quark–parton model, and maybe we add some asymptotic QCD corrections to the quark parton model, etc. We have to be able to bridge this gap and that is a non-trivial problem. As far as I am concerned, it is an unsolved problem. It is a marvelous problem. There are various ways of trying to bridge this gap. One is you say you simply boost the nuclear physics to the infinite–momentum frame. Now you cannot do that, in principle, unless you have a relativistic model in the nuclear domain. You cannot unambiguously boost an intrinsically non–relativistic model. You do not know how to do it. So there are basic ambiguities in making this connection if you start with a non–relativistic description. Alternatively, you can start by working with light–cone variables, which is an admirable way to go about the problem. Weber talked about that. When you work with the light–cone variables, you have the scaling variables built in. The price you pay for this is that you lose your simple physical intuition. For example, things do not commute that are supposed to commute. You lose your simple physical intuition when you try and develop models. You have to work very hard to try and develop that intuition and communicate it to others, because it is a different way of thinking about things. And then another way to do it is through the evolution equations. You use the renormalization group equations to evolve into the scaling region, but at some point you have to specify your wave functions. Your low momentum behavior must be specified. There have to be subtraction points, and one has to put in some information at these points. It seems to me that is where you make your connection with non–relativistic, or low–energy models. You try and bring these models up to that level and then you use the evolution equations to get into the deep inelastic region. One has to remember that one of the primary reasons QCD was developed as a non–abelian local gauge theory is because it gives rise to asymptotic freedom and scaling. Most of the models that we construct in the low–energy domain do not give rise to scaling, and do not give rise to asymptotic freedom. One has to find some way to join these on unambiguously so that we can, in fact, talk about both regimes at once. I think that is a crucial problem and one I want to work on myself.

The next level of theory is to take that lagrangian of QCD and calculate baryon structure; of course, it is a very tough problem. I have already talked about that. You have to generate confinement. You have to generate the mesons. You have to generate chiral symmetry breaking. You have to generate meson dynamics. You have to generate baryon dynamics. And I do not think you can do it without using physical insight along the way. But again, put it in perspective. Think about where we have come in one person's lifetime. We did not even know there was a neutron in 1931, or a proton in 1900.

On the experimental side, and again I emphasize the electromagnetic part, not to neglect the hadronic part but just because the electromagnetic part is the one I have been thinking about most, it seems to me we have to do an *order of magnitude* better than what has already been done if we want to make a significant impact on the rest of physics. If we do not want to just sit here talking to ourselves, but if we want to make a significant impact on the rest of the world, then we need to do at least one order of magnitude better than what has already been done. We cannot just redo things slightly better. And, we will have the capability of doing that—measuring angular distributions, using polarized beams, using polarized targets—we will have the capability with the intense CW machines, of doing that. We must include backgrounds in the analyses and do a good job on these backgrounds. It is no longer enough to talk about a resonant amplitude by itself or a background amplitude by itself. I think Mukhopadhyay has done the best job I know of on the background in the delta region, and it is essential even in the delta region. You see that 50% of the inclusive cross-section is background when you look at the inclusive spectra. So you must do a good, comparable job on the background as well as on the resonances. It is a long, tough, program and to me it is only going to pay off if we can improve the state of the world's knowledge by at least an order of magnitude.

So, let me just close with some thoughts on CEBAF. John Domingo talked to you about CEBAF. CEBAF is meant to be a facility which will allow you, and by you I mean everybody in this audience, to study these questions and make fundamental contributions to this area of science. My version of CEBAF's scientific goal is this:

CEBAf's scientific goal is to study the structure of the nuclear many-body system, its quark substructure, and the strong and electroweak interactions governing the behavior of this fundamental form of matter.

Here I would include B=1 as a nuclear many–body system—just look at that cartoon and you see the nucleon itself is one of the most interesting many–body systems because it exhibits all of the interesting features.

I will also give you a quote from the Vogt Committee report which was the last national committee to review the top priority given to CEBAF by the nuclear physics community for new construction in this country:

"The search for new nuclear degrees of freedom and the relationship of nucleon-meson degrees of freedom to quark-gluon degrees of freedom in nuclei is one of the most challenging and fundamental questions of physics."

Here again I include B=1.

Finally, I would just close with the observation that really what we are working on and what we are discussing here is the structure of matter and the nature of the fundamental forces, and what could be of more scientific importance and significance than that.

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FIGURE CAPTIONS

Figure 1. History—from talk of E. Golowich

Figure 2. Low-lying spectrum of the baryon (B=1)

Figure 3. The SLAC experimental inelastic spectrum at $\epsilon_1 = 7$ GeV, $\theta = 6°$, resolved into Breit-Wigner resonances by the fitting procedure discussed in the text [1].

Figure 4. Same as Fig. 3 at $\epsilon_1 = 10$ GeV [2]

Figure 5. $d\sigma_{in}/d\sigma_{el}$ at 6° for the $3/2^+$,3/2 (1236) resonance Experimental points are from SLAC Group A and the resonance analysis of Breiddenbach [2]. The predictions of models I and II (defined in the text) are indicated [3, 4, 5].

Figure 6. Same as Fig. 5 for the 1520 MeV resonance region. Also shown is the pure threshold behavior.

Figure 7. Same as Fig. 6 for the 1688 MeV resonance region

Figure 8. Same as Fig. 5 for the 1950 MeV resonance region

Figure 9. $(|f_+|^2 + |f_-|^2)/G^2_{Ep}$ and $|f_c|^2/G^2_{Ep}$ for the $3/2^+$, 3/2 (1236) resonance [3]. The predictions of models I and II (defined in the text) are indicated. References for the experimental data are found in [3].

Figure 10. Inclusive electron scattering from ^{12}C (contribution of R. Sealock *et al*, to this conference)

Figure 11. Same as Fig. 10 for iron

Figure 12. Picture of the nucleon in the standard model

Figure 13. Coincident electron scattering

HISTORY

1905	PROTON
1910	NUCLEUS
1932	NEUTRON
	ISOSPIN
1947	PION
1952	Δ RESONANCE
1956	CHARGE RADIUS
1958	V-A THEORY
1960	CHIRAL SYMMETRY
1962	SU(3) SYMMETRY
1964	QUARK CONCEPT
1967	SCALING IN DILS
1969	PARTONS
1973	QCD
1987	STRANGENESS CONTENT
	SPIN STRUCTURE

Figure 1

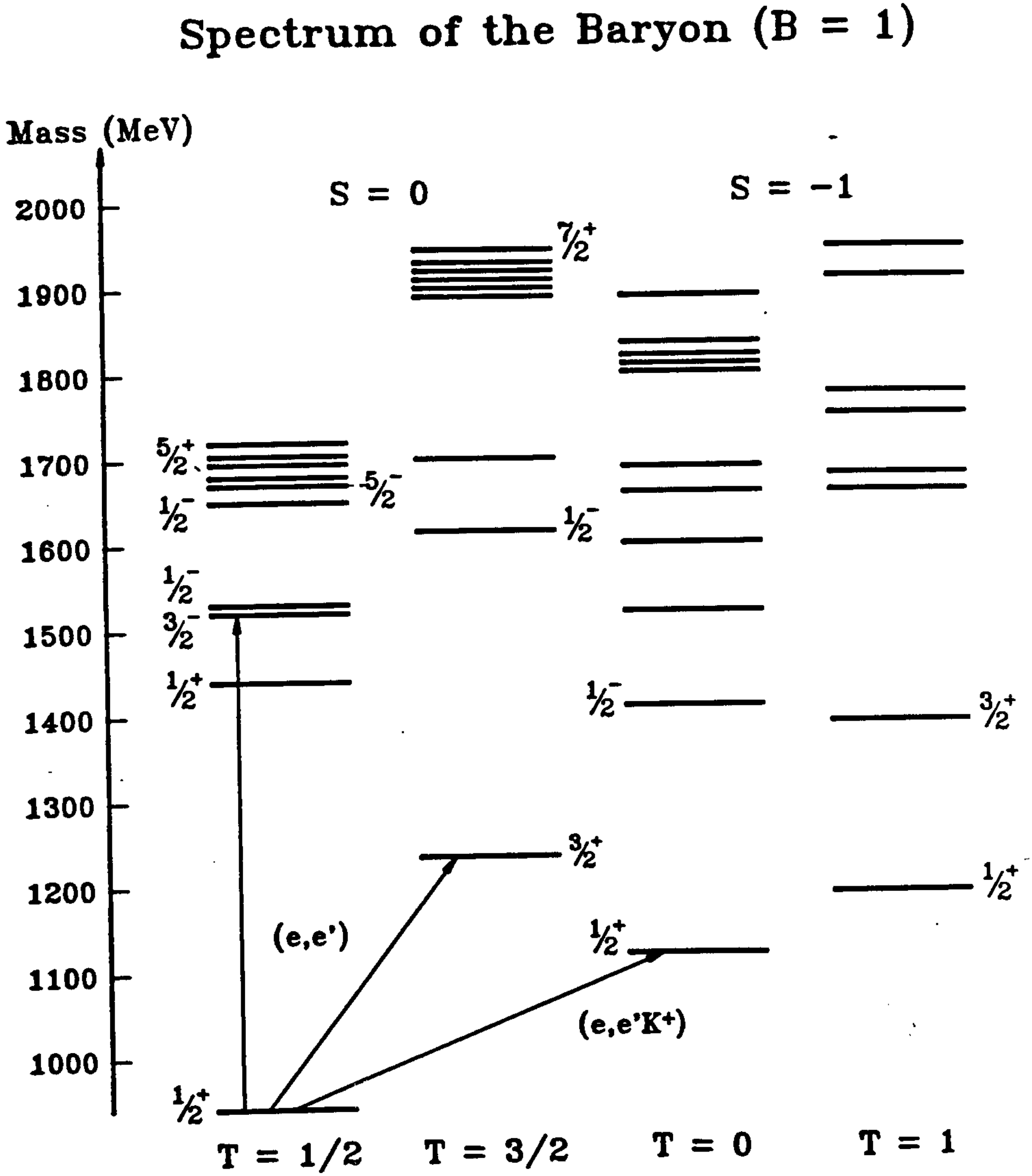

Spectrum of the Baryon (B = 1)
Mass (MeV)
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
S = 0
S = −1
7/2+
5/2+
5/2−
1/2−
1/2−
3/2−
1/2+
1/2−
1/2−
3/2+
3/2+
1/2+
1/2+
1/2+
(e,e')
(e,e'K+)
T = 1/2
T = 3/2
T = 0
T = 1

Figure 2

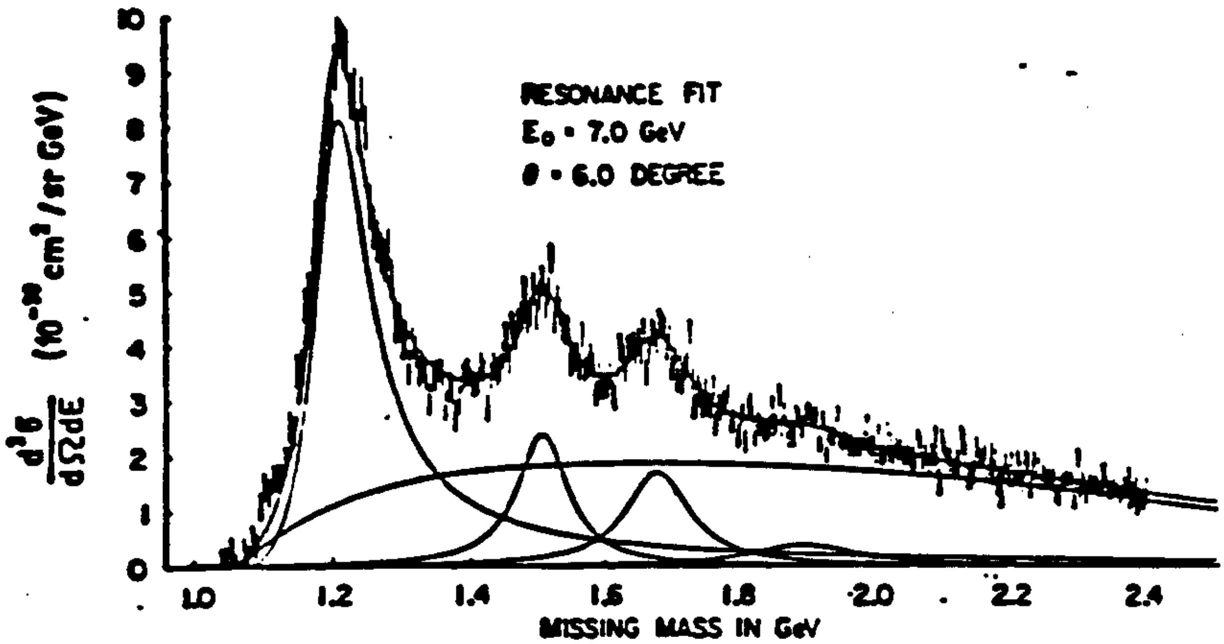


Figure 3

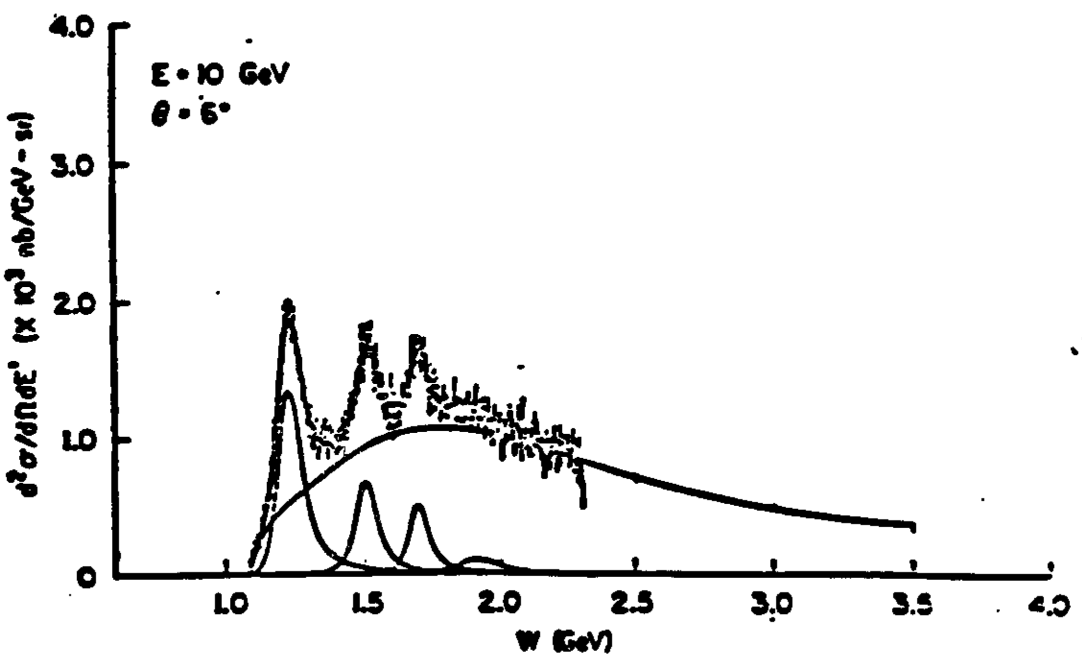


Figure 4

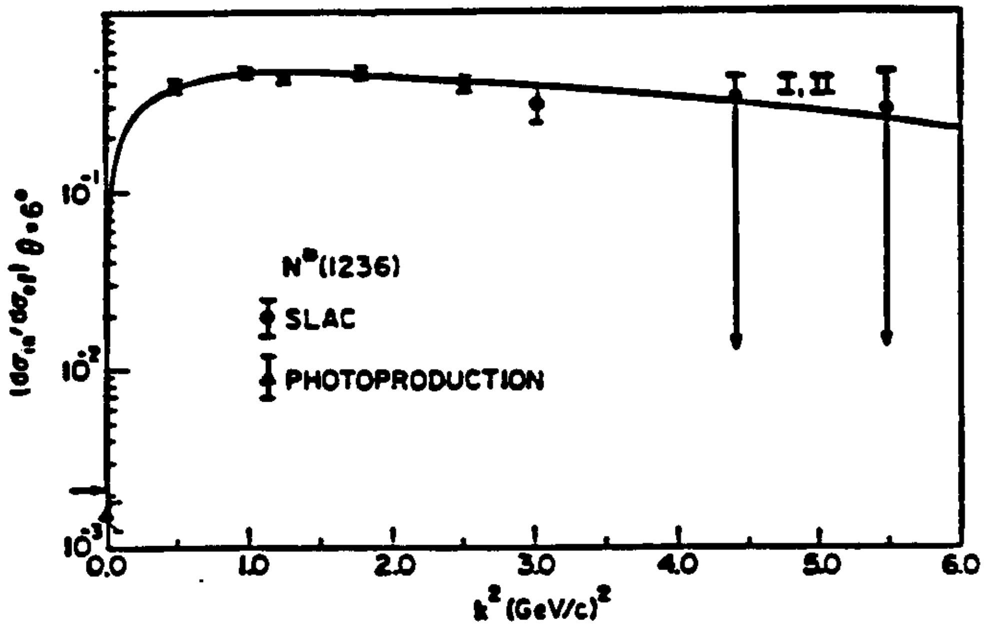


Figure 5

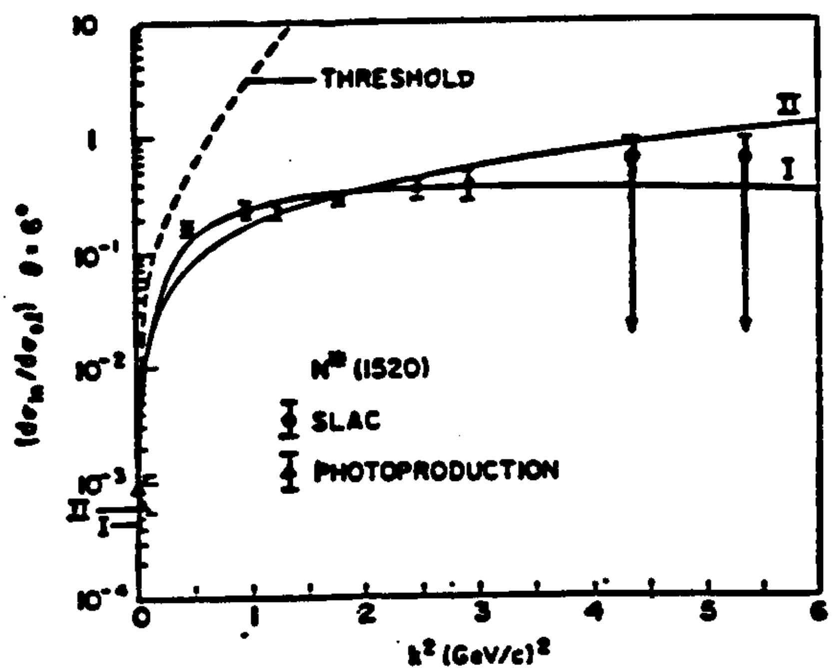


Figure 6

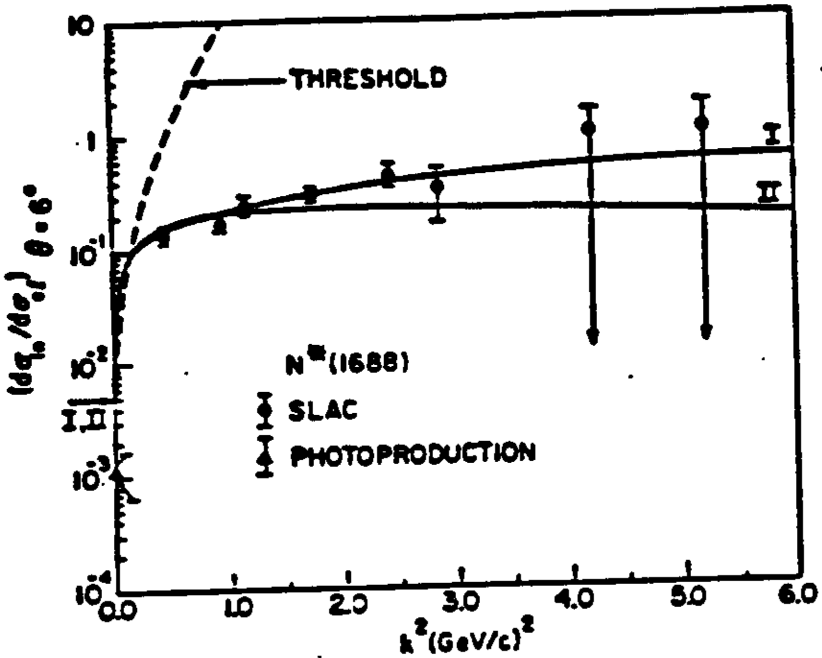


Figure 7

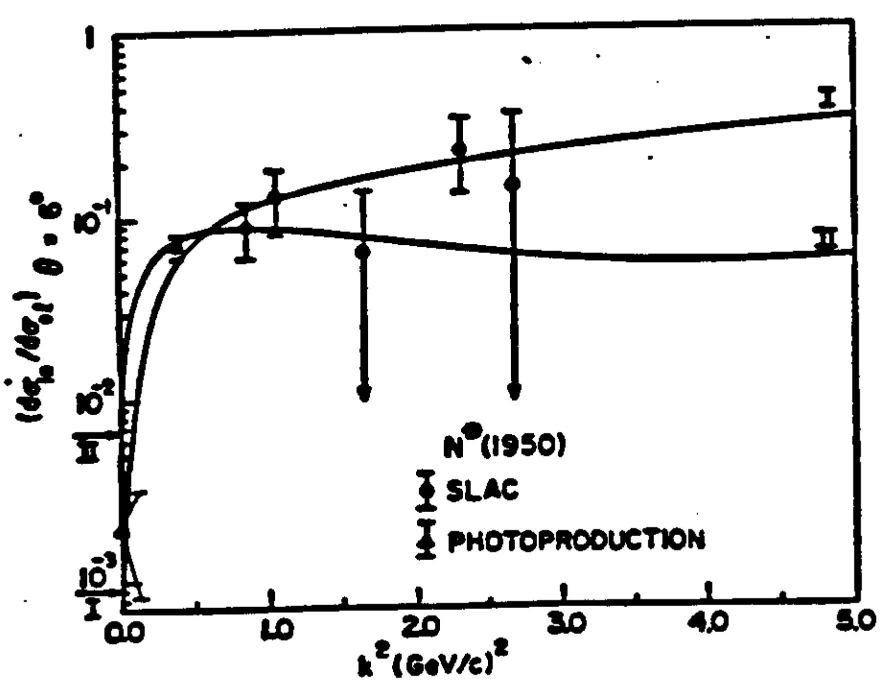
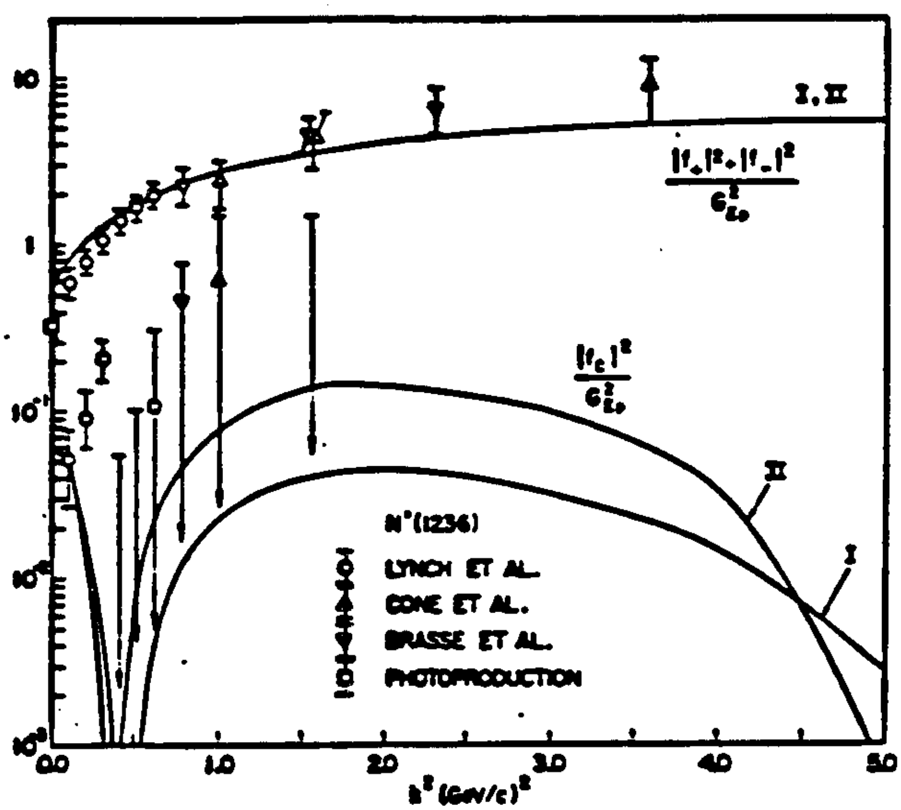
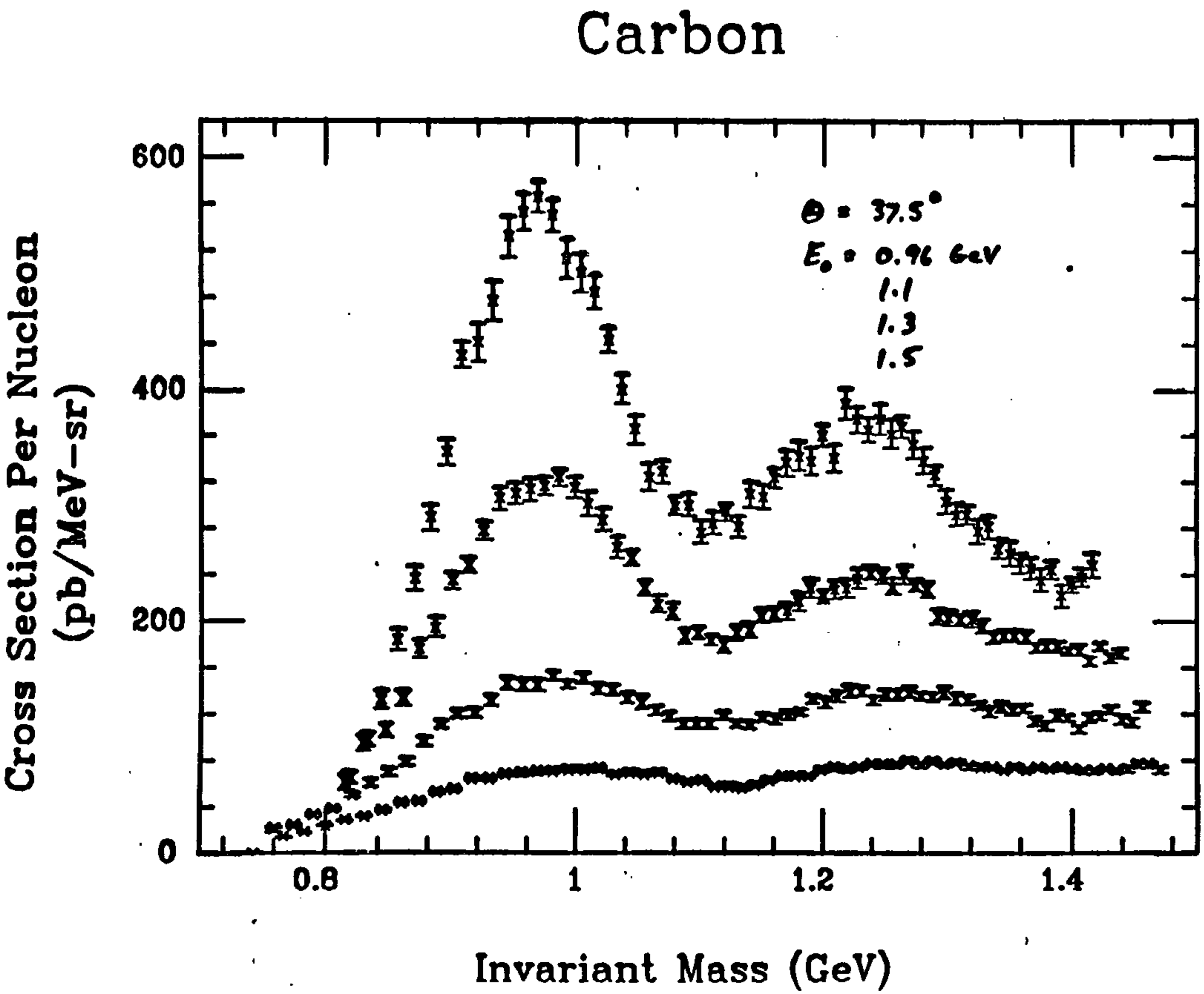


Figure 8



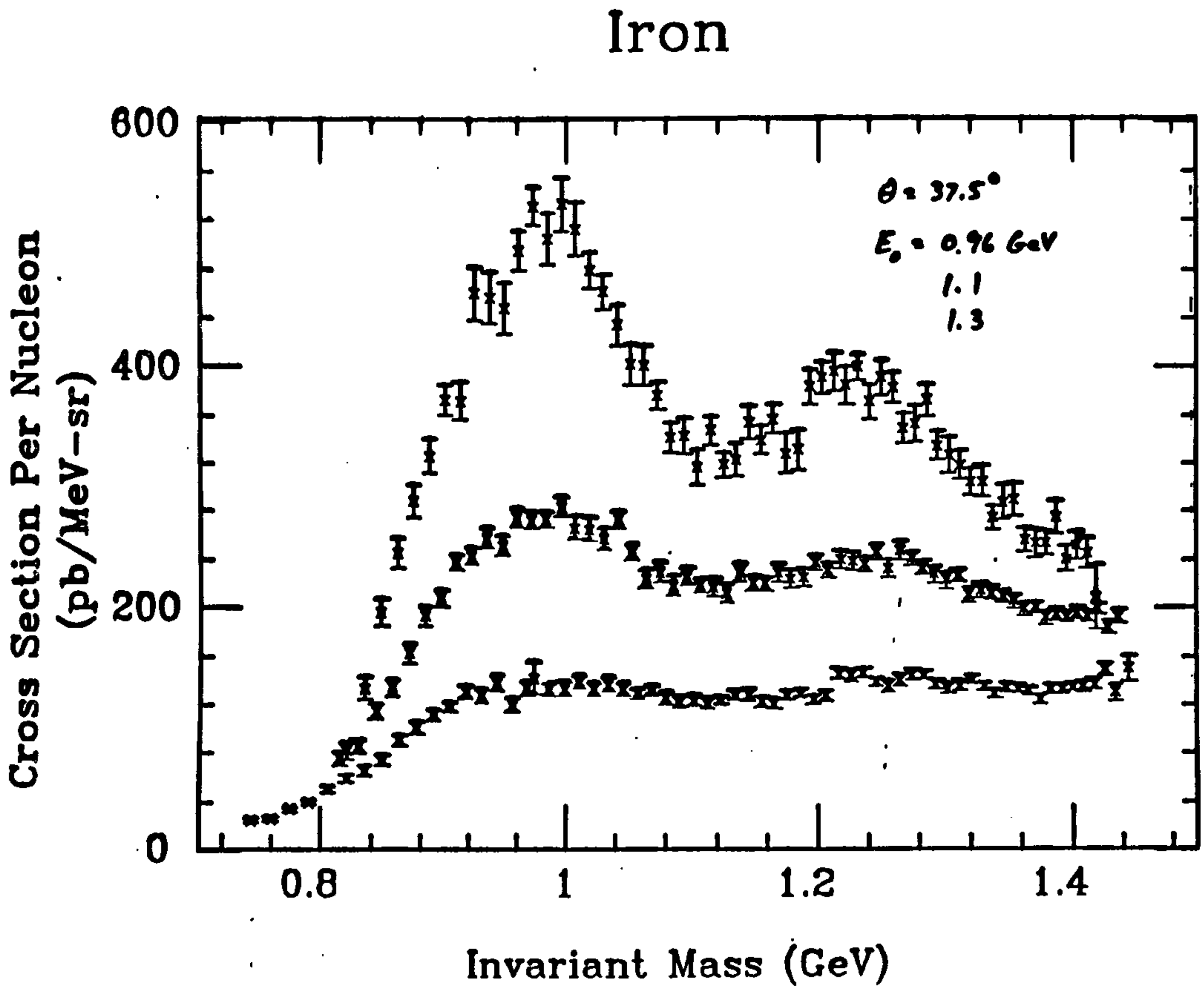
10
1
10^{-1}
10^{-2}
10^{-3}
0.0
1.0
2.0
3.0
4.0
5.0
k^2 (GeV/c)^2
I, II
$\frac{|f_+|^2+|f_-|^2}{G_{E_0}^2}$
$\frac{|f_c|^2}{G_{E_0}^2}$
II
I
N*(1236)
LYNCH ET AL.
CONE ET AL.
BRASSE ET AL.
PHOTOPRODUCTION

Figure 9



Carbon
Cross Section Per Nucleon
(pb/MeV–sr)
600
400
200
0
0.8
1
1.2
1.4
Invariant Mass (GeV)
θ = 37.5°
E₀ = 0.96 GeV
1.1
1.3
1.5

Figure 10



Iron
θ = 37.5°
E₀ = 0.96 GeV
1.1
1.3
600
400
200
0
0.8
1
1.2
1.4
Cross Section Per Nucleon (pb/MeV–sr)
Invariant Mass (GeV)

Figure 11

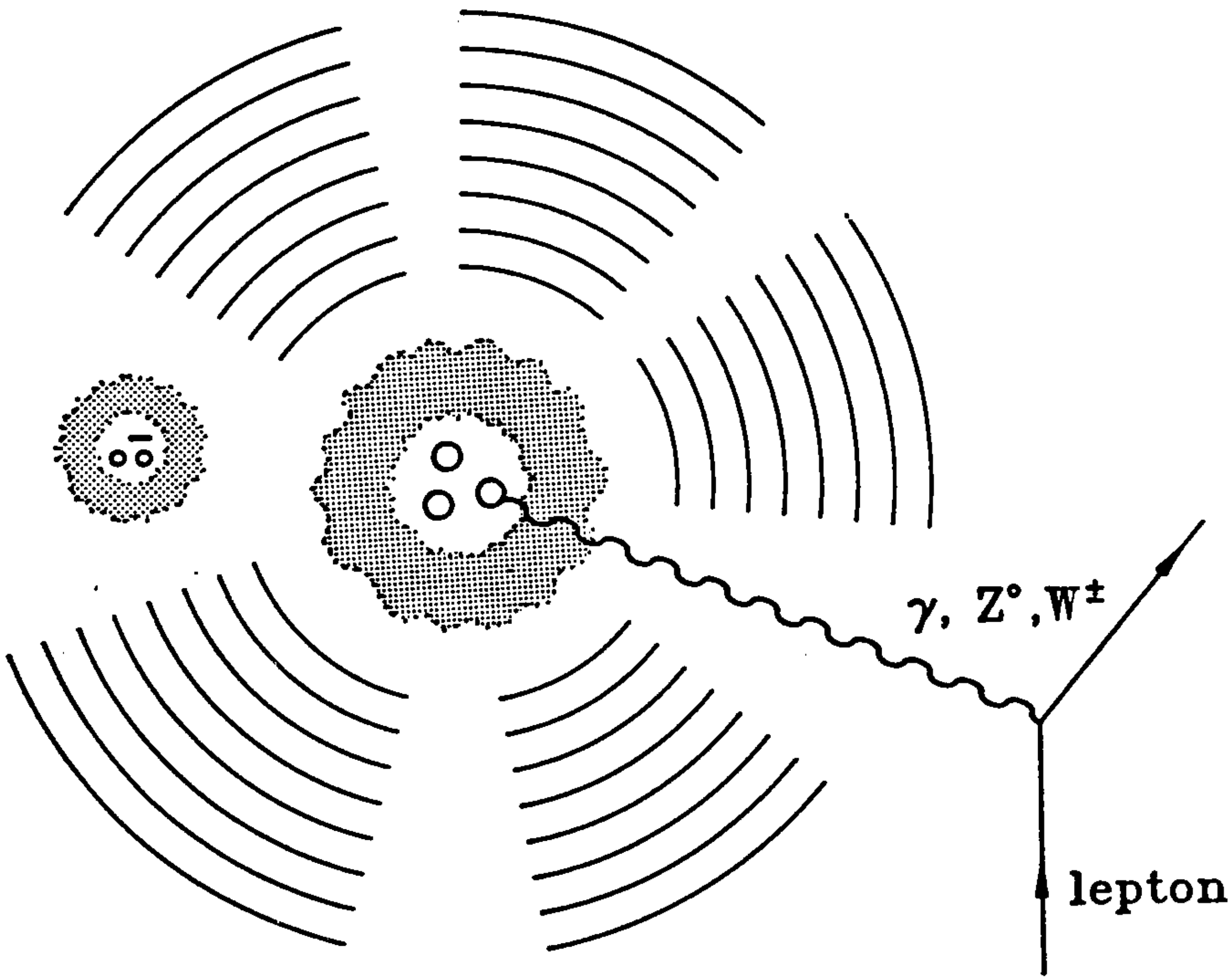
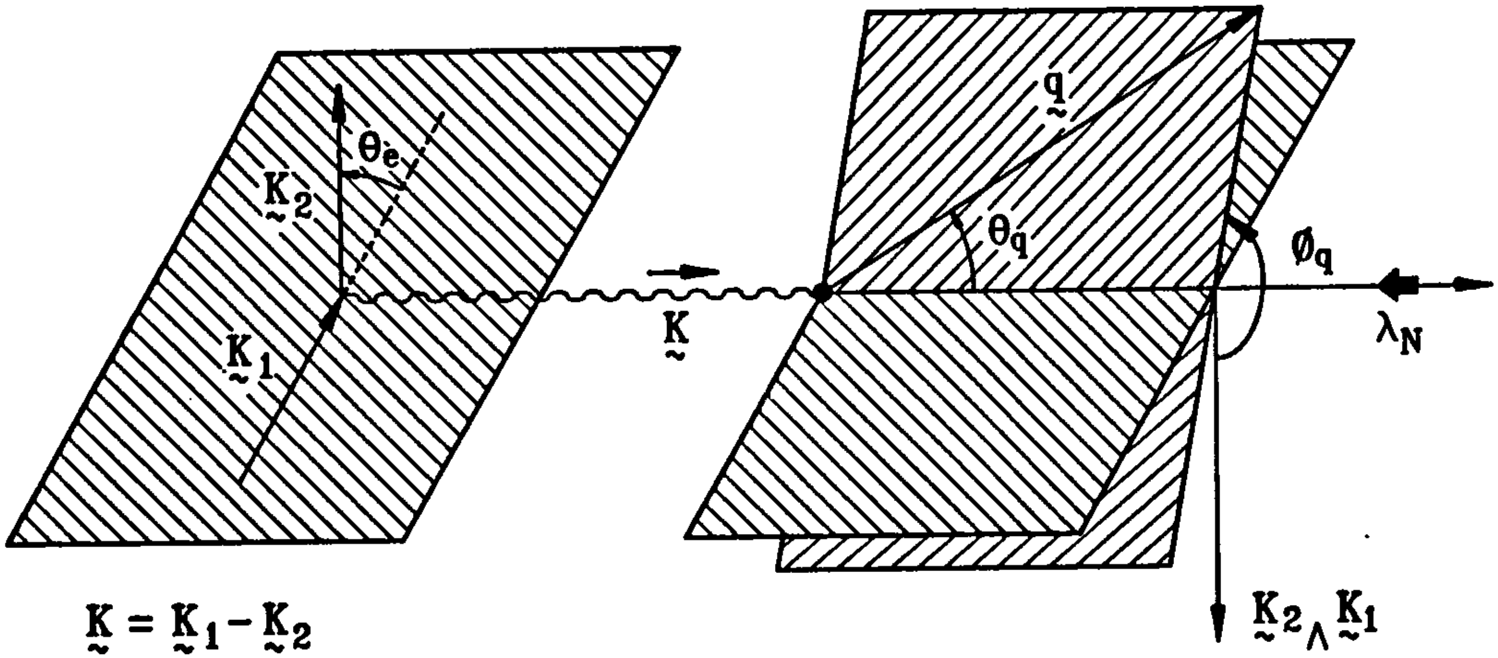


Figure 12



θ_e
$\underset{\sim}{K}_2$
$\underset{\sim}{K}_1$
$\underset{\sim}{K}$
$\underset{\sim}{q}$
θ_q
ϕ_q
λ_N
$\underset{\sim}{K}_2 \wedge \underset{\sim}{K}_1$
$\underset{\sim}{K} = \underset{\sim}{K}_1 - \underset{\sim}{K}_2$

Figure 13